AIR FORCE INSTITUTE OF TECHNOLOGY
GRADUATE SCHOOL OF ENGINEERING & MANAGEMENT
RESEARCH NEWS

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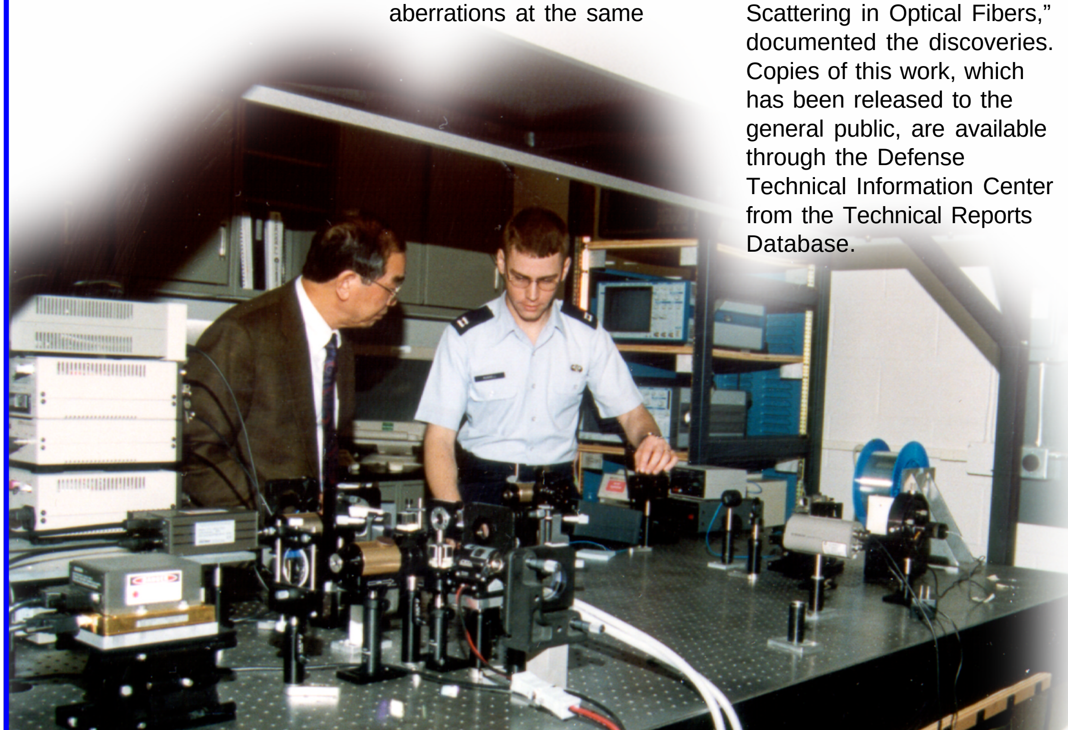
Laser Science Discovery – A Step Forward in National Defense

The Department of Defense has identified laser systems as critical to the modern military. They are used for numerous applications including detection, targeting, laser radar, remote sensing, munitions guidance, and even as weapons. To be effective, most of the applications require high intensity illumination of the target. Great care is taken to ensure high quality laser beams. Unfortunately, high powered lasers tend to be poor in beam quality. New methods must be developed to improve the beam quality of high power systems.

The Air Force has been developing efficient, compact, reliable high-energy laser systems for many applications ranging from anti-missile defense to laser radar and electro-optic countermeasures. One approach to high-energy devices is to couple and phase a multitude of smaller units to produce a single high-energy beam.

A recent research investigation done at the Air Force Institute of Technology (AFIT) demonstrates a new nonlinear optics technique for combining multiple laser beams into a single coherent beam while cleaning up the wave front aberrations at the same time. The technique is based upon Stimulated Brillouin Scattering (SBS) in a multimode optical fiber. The SBS process was found to combine multiple laser beams into a single spatially coherent source.

The AFIT Research Group, led by professor of engineering physics Won B. Roh, was sponsored by the Air Force Office of Scientific Research. The research was conducted at the AFIT laboratory (Wright-Patterson Air Force Base, Ohio) and the Air Force Research Laboratory (Kirtland Air Force Base, New Mexico). Captain Timothy H. Russell's dissertation, "Laser Intensity Scaling Through Stimulated Scattering in Optical Fibers," documented the discoveries. Copies of this work, which has been released to the general public, are available through the Defense Technical Information Center from the Technical Reports Database.



U.S. Air Force physicists Professor Won B. Roh and Captain Timothy Russell research combining multiple laser beams into one coherent beam. (U.S. Air Force photo by Kevin Pope)

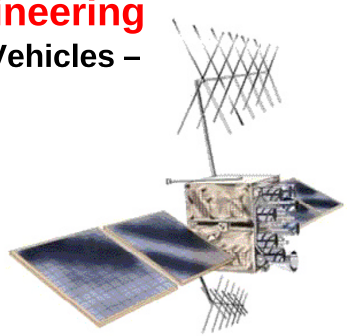
Center For Directed Energy

AFIT's Center for Directed Energy supports Air Force and Departmer of Defense agencies in transitionir high energy lasers and high powe microwaves to the battlefield through vigorous scientific and engineering research, graduate education programs, and diverse consulting activities. The Institute first developed a high energy lase program at the request of General Donald Lamberson in 1970. Since then, AFIT has educated 83 Docto of Philosophy (PhD) and over 160 Master of Science (MS) students who have led the development of directed energy weapons. Two AFI PhD's served as director of the Air Force laser program, one MS graduate was a co-inventor of the Chemical Oxygen-Iodine Laser, ar four AFIT PhD's led the team demonstrating a 40 kW laser for anti-satellite missions in the mid 1980's. More than 15 members of the AFIT faculty have established a strong record of success including 83 journal articles, 79 research grants, and more than 100 conference presentations in the past five years. Major research thrusts at AFIT include chemical lasers, photonic devices, imaging, remote sensing, and high power microwaves. The Center intends to educate a new generation of US citizens to assure the preeminenc of our air and space forces. For more information visit:
http://en.afit.edu/de/

Student Research CORNER

Aeronautical Engineering

Design of Aerospace Vehicles – New Technique



In the design of aerospace vehicles, designers are looking for ways to computationally model prospective vehicle configurations quickly. As designs become more complex, the designer may not be able to accurately model even the initial design variations. Major John S. Anttonen developed a new technique called Multi-POD that allows the rapid design development of high performance aerospace vehicles. His approach is contained in his dissertation, "Techniques for Reduced Order Modeling of Aeroelastic Structures with Deforming Grids."

Inflatable Space Structures – Overcoming Launch Constraints

Launch restraints limit the size of space structures. Innovative research into modeling inflatable, light-weight structures which can break this barrier was the subject of a recent research project. The finite element methodology applied to nonlinear beam and circular membrane models produced insight for future design decisions. Captain James W. Roger's dissertation, "Modeling Axisymmetric Optical Precision Piezoelectric Membranes," provided a dramatic improvement in modeling inflatable spacecraft (used for reconnaissance and energy transmission).

U.S. Air Force engineers prepare inflatable membrane for testing. Looking a lot like a giant contact lens, this experimental lightweight device may pave way for future, inexpensive weight-saving technologies that enable large space structures. (Photo: U.S. Air Force)

Electrical Engineering

An Advance in Aircraft Ranging To Ground Targets

Air Force fighter and surveillance aircraft acquire ground targets with pulse Doppler radar in the presence of ground clutter. Airborne pulse Doppler radar suppresses ground clutter by transmitting a high pulse repetition frequency (PRF) and employing Doppler filter banks to increase the signal-to-clutter ratio. The high-PRF waveform results in ambiguous range. Additional problems include ghosting (false targets) and eclipsing.

Nonlinear suppression (NLS) eliminates unwanted ranging effects of the PRF. The wide use of digital signal processing (DSP) makes feasible the implementation of NLS for ambiguity resolution and clutter suppression. Major J. M. Anderson's dissertation, "Nonlinear Suppression of Range Ambiguity in Pulse Doppler Radar," expands the NLS concept using discrete coding and processing.

A B-52H drops a load of M117 750lb bombs. During Desert Storm, B-52s delivered 40 percent of all the weapons dropped by coalition forces. (U.S. Air Force photo by Master Sgt. Ralph Hallmon)

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Problem Solved – Optimal Flight Path to Minimize Detection by Radar

The Air Force is expanding the uses and roles of the Uninhabited Air Vehicles (UAVs). Traditionally used for reconnaissance, UAVs are now being considered for combat operations. If these UAVs are to make effective contributions to air power, a progression from a single vehicle to multiple vehicle cooperative behavior is required.

Hierarchical decentralized controllers are being developed that combine guidance, real-time planning and multi-vehicle task coordination. These controllers will enable UAVs to coordinate threat avoidance, target search, classification, attack, and battle damage assessment tasks. Also, dynamically-coupled formation controllers will allow drag-reducing flight formations and will enable in-flight refueling for UAVs. Lastly, intelligent controllers will be able to learn from experience and revise the UAV's trajectory accordingly.

An AFIT research project provided a mathematically rigorous approach to air vehicle path planning. A number of fundamental insights were discovered into the radar exposure minimization path planning problem. Key results included the identification of limits on the existence of optimal trajectories, development of geometric conditions dictating when it is preferable to go-around or between two radars, and a cooperative control law for radar exposure minimization.

The research explored optimal path planning for air vehicles. An air vehicle exposed to illumination by a tracking radar is considered and the problem of determining an optimal planar trajectory connecting two locations is addressed. An analytic solution yielding the trajectory minimizing the received radar energy reflected from the target is derived using the Calculus of Variations. Additionally, the related problem of an air vehicle tracked by a passive sensor (infrared seeker or RF jammer) is also solved.

Using the insights gained from the single air vehicle radar exposure minimization problem, a hierarchical cooperative control law is formulated to determine the optimal trajectories that minimize the cumulative exposure of multiple air vehicles during a rendezvous maneuver. Local and global optimality issues are explored. Lastly, an optimal minimum time control law is obtained for the search and target identification mission of an autonomous air vehicle.

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This project was sponsored by the Air Force Research Laboratory and the Defense Modeling and Simulation Office. The AFIT faculty advisor for the research was Professor Meir Pachter of the Department of Electrical and Computer Engineering. Captain Jeffrey M. Hebert's dissertation, "Air Vehicle Path Planning," presented this solution.

Faculty Focus: Fellow of the Institute of Electrical and Electronic Engineers

Professor Meir Pachter conducts teaching and research as a faculty member in the Department of Electrical and Computer Engineering in the Graduate School of Engineering and Management at AFIT. He was recently elected a Fellow of the Institute of Electrical and Electronic Engineers. He earned his Batchelor of Science, Master of Science and Doctor of Philosophy Degrees from the Israel Institute of Technology.

Dr. Pachter's fields of expertise include automatic control of aircraft and missiles, adaptive control and system identification, inertial and Global Positioning System Navigation, autonomous control/neural networks/fuzzy logic control, nonlinear control and applied mathematics. Dr. Pachter has published papers in these areas and in differential games, robotics, and the theory of computational geometry. He was the faculty advisor to Captain Jeffrey M. Hebert's for his research work, "Air Vehicle Path Planning."

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RESEARCH NEWS

Basic research at the Air Force Institute of Technology is an important activity which leads to technological progress and the highest quality education. Research is an essential ingredient of academic life because it creates the questioning and creative background characteristic of graduate-level teaching and learning. AFIT's research focuses on support of the United States Air Force and the Department of Defense. AFIT students perform exciting research that has future applications in ensuring the technological supremacy of our nations defenses.

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